2016 IEEE International Conference on Computer and Information Technology

A Survey on Mobility Management Techniques in VANETs

Bilal Haider
Department of Computer Science,
Bahria University, Islamabad, Pakistan
bilalhaider@comsats.edu.pk

Ambreen Gul
Department of Computer Science,
COMSATS Institute of Information Technology,
Attock, Pakistan
ambrreengul@gmail.com

Shagufta Henna
Department of Computer Science,
Bahria University, Islamabad, Pakistan
shaguftahenna@gmail.com

Farhan Aadil
Department of Computer Science,
COMSATS Institute of Information Technology,
Attock, Pakistan
farhan.aadil@ciit-attock.edu.pk

***Abstract*—Vehicular Ad hoc Networks (VANETs) provide road safety, commercial, entertainment, and convenience services. Users have access to real time traffic updates, road hazard notifications, post crashed notification, remote vehicle diagnostics, audio and video streaming, and route suggestions to enhance the travel experience. However service delivery in VANETs suffers as nodes in VANETs move at high speed causing the network topology to change rapidly. A node becomes unreachable from its current point of attachment as it moves out of its range. Mobility management ensures that a mobile node can continuously access the services while it roams around by re-attaching itself via another point of attachment. Various solutions for mobility management have been proposed. Nonetheless handoff delay, packet loss and signaling overhead, and are still a concern in VANETs. Internet Engineering Task Force (IETF) has chartered a Distributed Mobility Management (DMM) group in year 2014. The purpose of DMM is to provide an alternate solution to the mobility management problem in wireless networks. In this research, the effectiveness of distributed mobility management schemes in VANETs is compared on the basis of different parameters.**

Keywords-VANET; MANET; Mobility Management; ITS; handoff;

I. INTRODUCTION *(HEADING 1)*

VANETs are interoperable wireless networks consisting of multiple vehicles and infrastructure elements. [1]. Each vehicle which is a mobile node (MN) contains an On Board Unit (OBU) which allows communication between vehicles in an ad hoc manner referred as Vehicle to Vehicle (V2V) communication. Vehicles are able to share information about an immediate or an escalating problem, for example an accident, road obstacle, or other lifesaving alerts which are time critical. Vehicles also communicate with infrastructure elements like Road Side Units (RSU) or a base station. This communication is called Vehicle to Infrastructure (V2I) communication. V2I allows the vehicle to acquire service and information updates from the service providers [2]. A vehicle may also acquire services by using a hybrid mode employing both the V2V and V2I communication. Service and resource provisioning can be difficult as vehicles tend to move at high speed and change their point of attachment (PoA) to the network. A node requires a reconnection to the network via a new PoA to ensure continuous access. This entire process is referred as mobility management.

Mobility management consists of three sub functions; location management, handoff management, and forwarding management [3]. Location management tracks a vehicle which may be inside the network or the vehicle might have traveled outside the network. Location management keeps the record of vehicle's location for the provision of service. Once service provision begins, a continuous connection to the vehicle is required even if the vehicle changes it PoA to the communication infrastructure, that is, changes its access point (AP) within the network or moves to a new network. This is referred as handoff management.

In general, handoff can be divided into two stages; handoff triggering (or handoff initiation) and connection re-establishment. Handoff process is initiated by a change of circumstances; which is normally triggered at layer 2 (L2), i.e., link layer or layer 3 (L3), i.e., network layer. For example if a change of AP is required in the same network due to signal strength reduction of current AP then handoff is triggered from L2. Similarly if a MN is moving to an AP of new network, e.g., due to high packet loss or increased delay in the current network, it will require a new address. In this case handoff is triggered at L3. When a L2 or L3 handoff is initiated, a new connection between the vehicle and the access network(s) is established via handoff signaling between the vehicle, previous PoA, and the new PoA. This process is called connection re-establishment. As handoff involves change in PoA, hence handoff management is specific to those vehicles which are connected directly to infrastructure, i.e., vehicles connected in V2I mode. Vehicles that are connected in V2V mode do not require mobility management and specifically handoff management.

978-1-5090-4314-9/16 $25.00 © 2016 IEEE
DOI 10.1109/CIT.2016.77

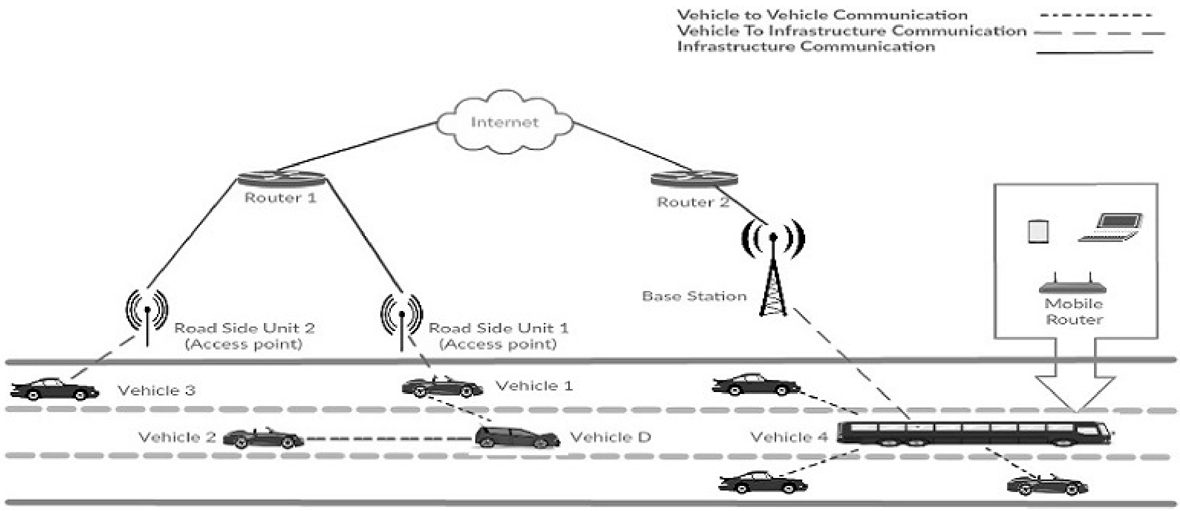

Figure 1. Vehicular ad hoc Networks

During service provisioning, packets are forwarded to the vehicle either directly or via some other network element. During handoff process packets may be channeled between the current PoA and new PoA. Once handoff process is complete, packets are forwarded via the new PoA. This process is referred as Forwarding Management.

Figure 1 depicts a typical VANET vehicle and a road safety service scenario. In Figure 1, vehicle D has suffered a road accident. This information is delivered to vehicle 1 and vehicle 2 by V2V communication. Vehicle 1 relays this information to the service provider via Road Side Unit 1, router 1, and internet. The service provider updates vehicle 3 and vehicle 4 via Road Side Unit 2 and base station. Vehicle 4 updates the vehicle connected to it via the mobile router (MR). In this manner all the surrounding vehicles are now informed of a nearby accident. It is important to note that if vehicle 3 and vehicle 4 are not connected with the infrastructure, it might be impossible to communicate the event to them as they are not in the range of vehicle D. Hence, to provide this information via V2I communication, it is critical that vehicle 3 and vehicle 4 are connected to the infrastructure and mobility management is supported by the infrastructure elements. Other VANET services including traffic efficiency, management services, and infotainment services may also be provided in the same way.

II. Issues of Mobility Management in VANETs

Frequent handoffs are common in VANETs due to high mobility of vehicles. These handoffs incur handoff delay and packet losses which degrades the services provided by a VANET. Further, high mobility may result in frequent network partitioning. This partitioning causes the path to become invalid and to be and they need to be rediscovered for service delivery.

Application layer mobility management solutions such as Session Initiation Protocol (SIP) [4] requires an external location management server in order to find the location of a MN when hand off occurs. Application layer solutions introduce a delay due to the message and response nature of these protocols. A MN may suffer for communication interruption during handoff. A re-invite message from a MN has to be sent to the Corresponding Node (CN). MN has to wait for a response of CN before it can resume communication [5]. Transport layer solutions such as Mobile Stream Control Transmission Protocol (mSCTP) [6] and TCP migrate [7] are not suitable in scenarios where both nodes are mobile unless support for other layers is provided [8] [9]. Similar to application layer solutions, transport layer solutions also require an external location management server. Furthermore, transport layer solutions do not support middle boxes.

Host based schemes, for example [11], [12], [13], [14] etc. discussed in literature review use forwarding pointers. They normally rely on a central anchoring point. All traffic from the MNs has to be routed via these central points [15]. These approaches suffer from problems such as longer paths as packets are forwarded by using pointers to PoAs along the way to the MN. Various types and quantity of messaging are required during the handoff process. An anchoring point may also become a bottleneck because all the traffic for the respective vehicles has to be routed through them [16].

Network based approaches, for example [14], [17], [18], etc. suffer from higher handoff delays if a MN enters a network whose gateway is not able to support host mobility. In case of such architecture, it is assumed that the same protocols are understandable by all the access networks, which is not possible in real world scenarios.

III. Litrature Review

Mobility support in IPv6 (MIPv6) [11] was introduced to provide global mobility management. This protocol allows a

Protocol	Handover Delay	Packet Loss	Cross Layer Communication	Signaling Overhead	Additional Support Required	Layer
SIP	Medium	High	Yes	High	Location Management	Application
mSCTP	Medium	High	Yes	Low	Location Management	Transport
TCP-migrate	Very large	High	Yes	Low	Location Management	Transport

TABLE I. APPLICATION LAYER AND TRANSPORT LAYER MOBILITY MANAGEMENT SOLUTIONS [10]

MN to move between different links without altering its HN IP address. Packets can be routed to the MN via HN independent to the current PoA of the MN. Figure 2 shows a variant of MIPv6 for VANET known as MMIP6 [36]. Each MN registers its IP address with a network entity known as a home agent (HA) of home network (HN) as shown in Figure 2a. Each MN has two addresses, home address (permanent address of the MN), and a care of address (CoA) (an address which a MN node uses when it is away from the HN). When a MN is away from the HN, the HA is responsible for intercepting, encapsulating, and forwarding packets destined for home address towards the CoA. Hence, forwarding management is distributed between the ends of the tunnel at HA and the MN as depicted in Figure 2b. Once the handoff is complete, the foreign agent (FA) in the foreign network (FN) forwards the packets to the MN as shown in Figure 2c.

HA and CNs are informed by the MN when MN moves to a FN. As location management becomes the responsibility of multiple network elements such as HA, FA, CN, and MN itself, a lot of signaling and computation resources are used.

Global mobility management requires excessive signaling and resource usage. The concept of Mobile Anchoring Points (MAP) was introduced in Hierarchical Mobile IPv6 (HMIPv6) [12]. HMIPv6 provides micro-mobility or local mobility by using MAP. MAP is not required in each subnet. Any of the network's routers can be assigned as MAP. Figure 3a shows two MAPs; one in HN and other one in FN. Local MAP updates may reduce the hand off delay incurred by the HA. Figure 3b shows, how MAP is able to manage the activities related with the mobility management including forwarding management and handoff management. However, periodic updates of CoA are required to be sent to the HA and CN as shown in Figure 3c. L. Osborne et al. [19] provided a comprehensive comparison of MIPv6 and HMIPv6.They concluded the need to develop a better mobility management protocol. B.D. Shin et al. [20] introduced the concept of Virtual MAP (VMAP) which is a router in between the actual MAP and the MN. The VMAP reduces the distance the signal has to travel to handoff, thus reduces the handoff delay.

Another scheme for fast handover in hierarchical mobile IPv6 networks (FMIPv6) [13], allows a MN to anticipate when a handoff could occur. MN informs its current MAP router that it wants to move. The current MAP sends its recommendation of a new MAP and a new CoA. The current MAP also informs the new MAP with the current CoA and recommends a new CoA. The new MAP acknowledges the validity of the new CoA. If the new CoA is valid, the old MAP arranges forward of packets for the MN to the new MAP. Otherwise packets are forwarded by using a tunnel between old CoA and new MAP. When MN reaches the new MAP it informs the new MAP to forward packets designated to the MN on the new COA. However, an excessive amount of signaling is required in order to predict the hand off. This effect is relative to the number of MNs currently attached to a MAP. Enhanced Fast handover with Low latency for MIPv6 [21] is an extension of FMIPv6 for VANETs. When a new MAP is assigned, it handles the new CoA configuration instead of the MN. The current MAP forwards the information of the MN to the new MAP. The new MAP confirms the new CoA to the current MAP which starts binding updates prior to the handoff and sends new CoA acknowledgement to the MN. Upon receiving the new CoA acknowledgement, MN starts L2 handoff. By the time the L2 handoff is complete, the HA and CN are aware of the new CoA sent by the current MAP.

Table 1 provides a brief comparison of host based mobility management protocols. These protocols require involvement of MN in mobility management related signaling. Network based protocols are independent of global mobility management protocol and localized mobility management for MN is not also required.

In Proxy Mobile IPv6 (PMIPv6) [22], a network is referred as local mobility domain (LMD). Each local mobility domain has a local mobility anchoring point (LMA). All the traffic from a MN is routed through the LMA. Each LMD may contain multiple mobile access gateways (MAG). A CN in PMIPv6 may reside within the LMD or outside of it. Two signals known as proxy binding updates (PBUs) and proxy binding acknowledgement (PBAs) are used to indicate whether handoff request is a new one or a from another MAG. An acknowledgement to PBU is sent by LMA to MAG. An acknowledgement contains MN-ID, MAG address, and prefix assigned to MN. Figure 4 portrays a MN moving from the range of MAG1 into the range of MAG2. MAG1 and MAG2 handle mobility management by communicating with a LMA. However, a MN may suffer from longer handoff delay while moving between two LMDs.

In inter-domain handover scheme, an intermediate mobile access gateway (IDiMAG) is used for seamless service in vehicular networks [17]. This scheme introduces a new element called iMAG between the home and foreign LMAs. iMAG is connected to both LMDs. To reduce the long handoff delay when a MN moves between two LMDs, first L2 and L3 intra-domain handoffs are performed by the iMAG and MAG of first LMD. This is followed by inter-domain L3 handoff at iMAG, i.e., between two LMDs as iMAG is connected to both LMDs. Finally a L2 and L3 intra-domain handoff between iMAG and MAG of the second LMD is performed. Although longer delay due to L3 handoff is minimized, yet IDiMAG requires that the iMAG should be geographically located between the two LMD. This placement of iMAG is not feasible most of the time. Further information of all associated APs or RSUs of both LMDs has to be stored at iMAG which requires a lot of signaling and network resources.

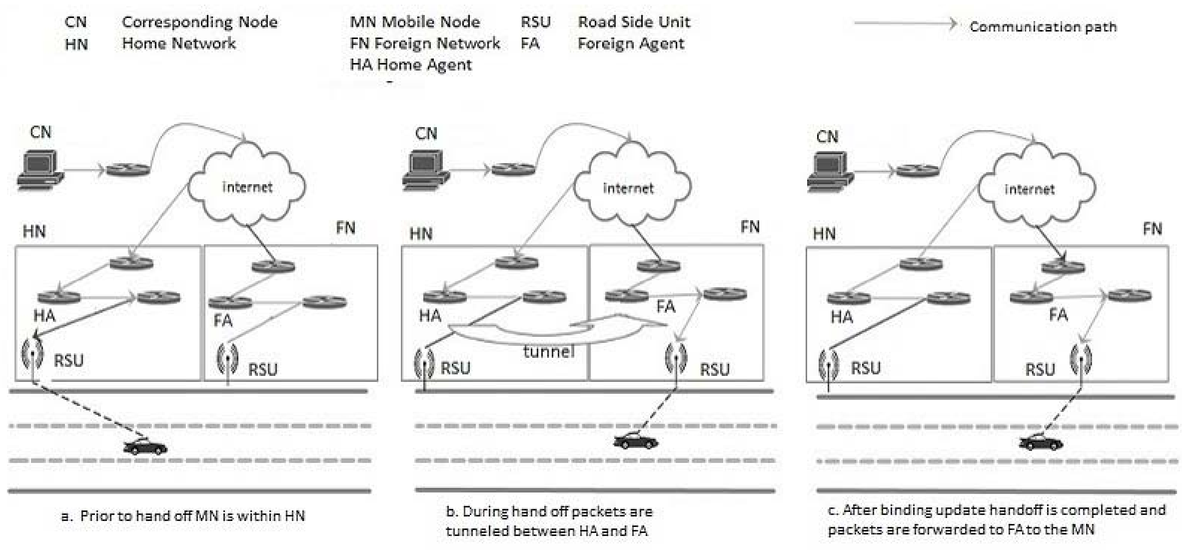

Figure 2. MMIP6

Devarapalli et al. introduced the concept of mobile network also referred as NEMO, i.e., a network that moves to reduce the amount of signaling generated by large number of MNs [14]. Each NEMO has a MR that is responsible for attaching and re attaching the NEMO to internet via different connection points, while handoff is transparent to other MNs of NEMO. That is handoff management on behalf all MNs in the network or subnet associated with a particular MR, is responsibility of that particular MR. Each NEMO is a part of a HN and it shares addresses belonging to one or more address blocks of that HN. All packets of NEMO are forwarded to the HN as shown in Figure 5a.The MR of NEMO acquires a CoA of a visited network when it is not directly connected to the HN. This facilitates in packet delivery without worrying about the architectural details of routing mechanism of the network. Whenever communication between a node in NEMO and CN residing outside the HN is required, packets are forward from CN to HN, encapsulation is performed, and packets are forwarded to the CoA of NEMO's MR as shown in Figure 5b. MR de-capsulate the packets and forwards to the particular node of NEMO. After handoff is complete, packets are forwarded via the FN to the MR as shown in Figure 5c.

Mussabbir et al.[23] extended the idea of FMIPv6 to support NEMO solutions in VANETs. They added a new extension flag to differentiate a MN from a MR of a mobile network. Moreover, they introduced Fast Binding Update message (FBU) and fast acknowledge messages. In order to confirm the acceptance of the request, a status field is introduced in the handshake acknowledgement message by MR. The protocol uses information IEEE 802.21: Media Independent Handoff Services [24] to acquire neigborhood information. The protocol also introduces the concept of tunnel management called TM. Each MAG has a TM cache to store the neighbourhood information and potential MAGs. Once a MN has sent a handoff request to current MAG (pMAG), handoff initiation and handoff acknowledgement messages are exchanged between the new MAG (nMAG) and pMAG. MN's ID is used to establish a tunnel between the two MAGs. pMAG also starts a life time for the tunnel. When a MN sends a report message to the previous AP that the signal strength has dropped, the pMAG and nMAG use the pre-established tunnel for packet forwarding. In case of failure of report within the life time, the entries in both MAGs for the MN are removed. As soon as the MN connects with the new AP, it starts receiving packets from the nMAG.

A real bus scheme is proposed by Y.-S. Chen et al. [18]. In this scheme, buses are selected as MRs. Buses are assumed to have two routers, one each at the front and at the back. The front and rear routers take care of the handoff process by receiving information and completing the hand of process respectively. Extending the above idea, a virtual bus scheme using three or more vehicles with single MRs is also proposed. Handoff delay can be further reduced by integration of NEMO with a multicast based solution. However, multicast groups may introduce extra overhead because of multicast group management.

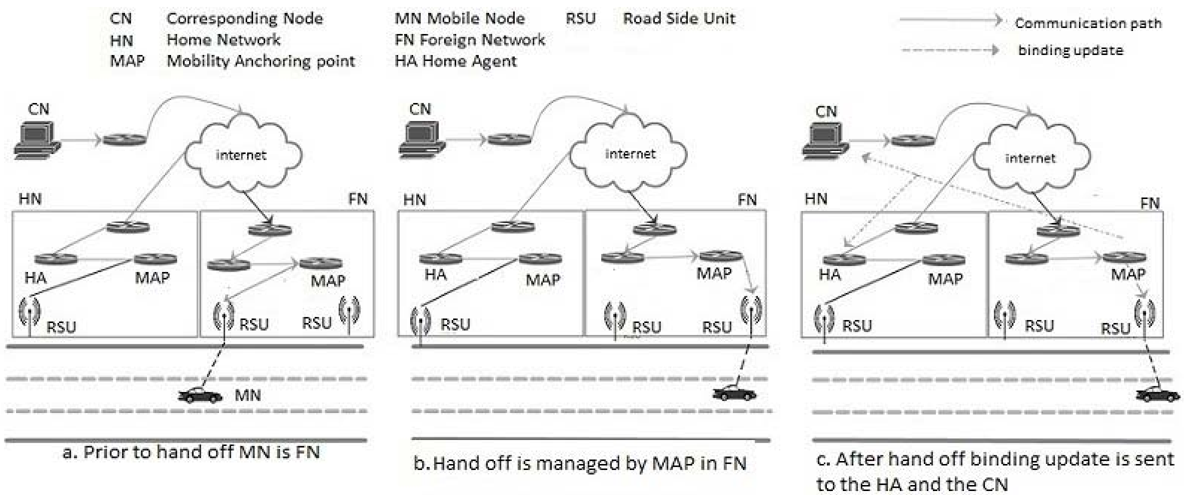

Figure 3. Hierarchical Mobile IPv6

NEMO-based VANETs (VANEMO) [25], is based on a vehicle assisted cross-layer handover (VACH). In VACH nearby mobile nodes assist the handover process. In this scheme, a MN broadcasts a control signal to defer the current communication with the other MN, and communicates with a MN with highest priority in front of it called MNHF. MNHF provides the MN with the details of new CoA. While still connected with AP1, and receiving data from AP1, MN configures to this new CoA for AP2. In order to minimize the packet losses, MN connects with a MN having highest priority to its rear called MNHR, which is still connected to AP1. During the handoff period, MNHR receives the packets which are required to be delivered to the MN. After completing the handoff, MN sends updates to the HA to create a tunneling between the old and new CoA. HA intercepts, encapsulated and forwards the packets to the new CoA of MN. Finally, MNHR sends packets destined for MN and communication session between MN and MNHR is terminated.

Protocol	Handover Delay	Packet Loss	New Elements	Cross Layer Communication	Signaling Overhead
MIPv6/MMIP6	Very High	High	HA,(FA for MMIP6 only)	No	High
HMIPv6	Very High	Medium	HA,MAP	Yes	Low
VMAP-HMIPv6	Medium	Medium	HA,MAP,VMAP	Yes	Low
FMIPv6	Low	Medium	HA,MAP,	Yes	High
Enhanced FMIPv6	Low	Medium	HA,MAP,	Yes	Medium

TABLE II. COMPARISON OF HOST BASED MOBILITY MANAGEMENT PROTOCOLS

D. Yogesh et al. [15] discussed variants of handoff scheme such as MIPv6, HMIPv6, PMIPv6, and FMIPv6 in the context of VANETs. The authors conclude that there is still margin to improve mobility management and handoff protocols. Most of the schemes discussed above in some form or another rely on a central anchoring point which performs mobility management, e.g., HAs, MARs, MAGs, LMAs, and MRs. Traffic routed to or from MNs has to pass through these central points. Centralized approaches for session management are subject to several problems including longer routes, signaling overhead, complex network architecture, and single point of failure.

D. Liu et al. [3] have discussed these issues in detail. The authors have argued that distributed mobility management architecture may reduce the inefficiency of centralized approaches. Distributed mobility management provides an alternate solution to the problems mentioned above. Unlike traditional network, the network is flattened and mobility is anchored close to the MN. Mobility management functions are distributed to various network entities. It is not necessary for the data and control messaging to go through a central component. Data packets travel in a distributed fashion whereas control packets maybe centralized or distributed among different network elements.

P. Sornlertlamvanich et al. [26] suggested a NEMO-based distributed mobility management design. In this scheme mobility anchors are deployed near the edge. Therefore, this scheme improves scalability and robustness

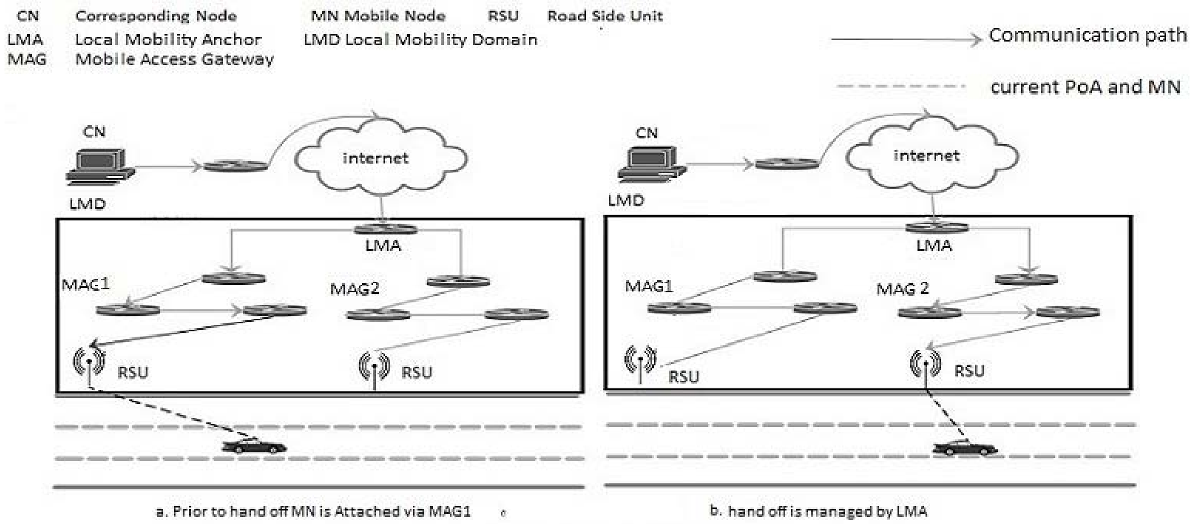

Figure 4. Proxy Mobile IPv6

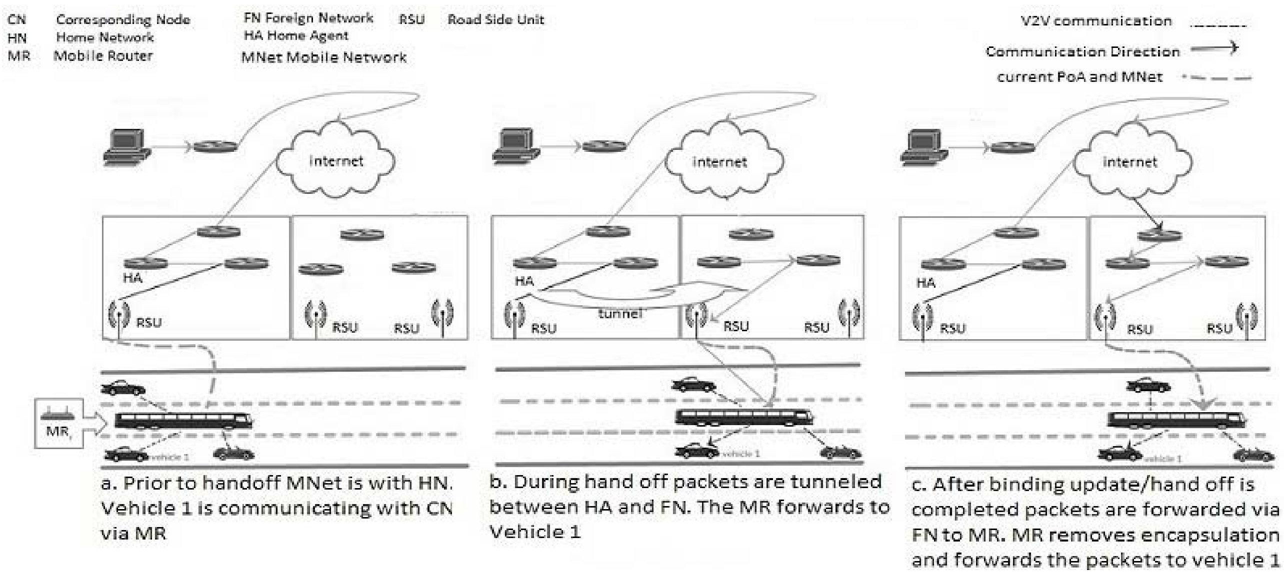

Figure 5. NEMO

of infrastructure. Authors argue that distributed approach reduces the handoff delay. The main feature in this concept is that the MR of NEMO is required to obtain a new network prefix for each mobility anchor it attaches itself to. This allows the NEMO to retain connection via network prefix assigned at previous mobility anchoring. New connections are created by using the current network prefix. When a connection is closed, the network prefix is detached.

Understanding the need to move from existing solution specific to various layers as list above, the DMM group was formed by IETF in 2007.The charter of DMM group was approved in year 2014 [27]. The group is responsible for specifying solutions for the IP networks. The focal points of the group as per the charter are:

- Architectures that move away from hierarchical schemes and centralized deployment model.
- Consideration of new developments and operational practice, for example, flattened network architecture and use of virtualization.

The key spotlight of the DMM group as per their charter is in mobility management anchoring. The group is authorized to add extension to existing MIPv6 family in particular and other IETF protocols in general. The group assumes IPv6 compatibility in all devices of the network. Another interesting element in the charter states that control and data packets may travel on a different path. Finally, mobility management related activities may be located at different network elements.

Protocol	**Handover Delay**	**Packet Loss**	**New elements**	**Cross Layer Communicati**	**Signaling Overhead**	**Additional Support**

				on		Required
PMIPv6	High(inter domain)	Low	LMD,LMA,MAG	Yes	Medium	No
IDiMAG	Medium	Low	LMD,LMA,MAG, iMAG	Yes	High	No
NEMO	Very High	High	HA,MR	No	Very High	Route optimization
FMIPv6 NEMO	Medium	Medium	HA,MAP,MR,TM cache	Yes	High	No
Real/virtual bus scheme	Low/High(with DHCP)	Medium	HA,MR	Yes	Low	Multicast group management
VACH	Medium	Medium	HA,MR	Yes	High	No

TABLE III. COMPARISON OF NETWORK BASED MOBILITY MANAGEMENT PROTOCOLS

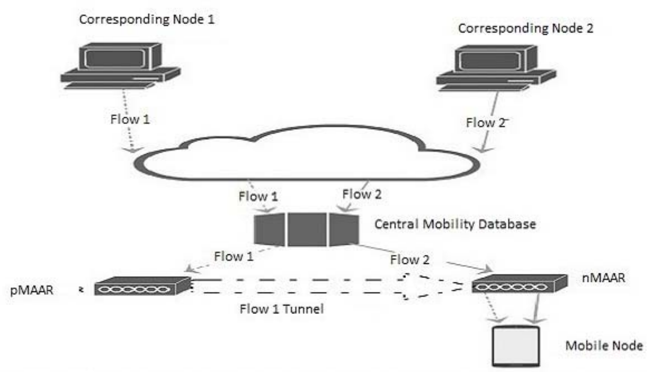

Figure 6. PMIPv6 based solution for Distributed Mobility Management

A work in progress by C. J. Bernardos et al. [28] currently submitted as a draft at DMM group, is a network-based distributed mobility management solution. It uses separate IP for flows associated with each anchor point. This requires each anchor point to maintain its own network prefixes of IPv6 addresses. Each anchor point assigns an IPv6 address to each MN that connects to it. It transfers flow forwarding task from LMA to Mobility Anchor and Access Router (MAAR). MAAR also has responsibilities similar to that of MAG in PMIPv6. This in turn converts the centralized solution of PMIPv6 to a distributed solution. When a MN node moves from on MAAR to another, flows are maintained at MAAR. Mobility is managed using a central mobility database (CMD). When a MN detects need for a handoff it sends a request to most suitable new MAAR (nMAAR). The nMAAR forwards the request to CMD. The CMD updates flow tables of nMAAR and the current/previous MAAR (pMAAR). After reconfiguring the flow tables, CMD sends an acknowledgement message to the nMAAR which forwards it to the MN. This is followed by establishment of a tunnel between nMAAR and pMAAR on which flows were previously running. As depicted in Figure 6, pMAAR is maintaining flow 1 whereas nMAAR is maintaining flow 2.

C. J. Bernardos et al. [29], have also proposed a host distributed mobility management approach. In this approach two new entities are added to the network structure; Distributed Anchor Router (DAR), and Home Distributed Anchor Router (HDAR). DAR is the first hop router to which the MN is currently attached. HDAR serves as a HA for a particular IPv6 address of MN. A MN may have multiple HDAR from where multiple flows were initiated as it moves along. When the MN moves from one DAR say pDAR to the next DAR say nDAR, the pDAR becomes HDAR for flows which started from pDAR.

IV. CONCLUSION

A variety of services which can be deployed on VANETs are large in number. Similar to any other network, minimum disruption in services provisioning is one of key factors effecting VANETs success. High mobility of nodes in VANETs requires a specific mobility management solution to ensure minimum handoff delay and signaling overhead during re-anchoring process. Traditional mobility management models of host and network mobility do not serve well in VANET scenarios. New approaches to distributed mobility management although seems a good candidate but it is yet to be tested in the field of VANETs.

Various mobility anchor positions have been used in scenarios discussed in the literature review ranging from the HA to MR. These mobility anchors manage details of location of the MN, perform handoff in association or without association of the MN, and forwards the packets before, during, and after hand off to the MN. It can also be deduced that in legacy protocols both control and data packets travel via or to a central point. If this central entity fails, the whole mobility management architecture fails. Based on the above discussion, the following questions arise

1. How effective are distributed mobility management schemes used in WLAN and MANETs when applied to VANETs paradigm?
2. What changes can be made for the selection of mobility management anchor in order to reduce handoff delay and signaling overhead?
3. How can control and data packets be separated in distributed mode order to avoid single point of failure of mobility management?
4. Is a distributed mobility management architecture better solution for improving the overall performance of VANET services?

V. FUTURE DIRECTIONS

A distributed mobility management solution can be used in VANETs and provide a reduced handoff delay and signaling overhead. Another approach that can be used is to find a method to dynamically assign mobility management functions to suitable network elements.

Section 5.1 5.2 and 5.3 are aimed to answer question 2 and 3 by outlining strategies which will be considered to reduce handoff delay, signaling overhead, and dynamic assignment of mobility anchoring function to network elements. Sections 5.3, 5.4 and 5.5 aim to answer questions 1 and question 4 of the Conclusion. They provided basis of how the comparison of proposed technique with legacy solution will be carried out; and effectiveness of proposed technique will be benchmarked for improved VANET service delivery.

A. Forwarding Pointer

MANETs and WLANs mobility management techniques based on flooding, broadcasting, routing table, and central database (in case of WLANs only) schemes might serve as a wrong choice for VANETS because VANETs are more dynamic in nature than MANETs and WLANs. Frequent disconnections due to high speed of nodes require frequent beacons, path rediscovery, and database updates. The proposed scheme would employ a variant forwarding pointer scheme in order to achieve a lower handoff delay and signaling overhead. In pointer forwarding, each vehicle is associated with

- Global unique address.
- Home address of stored HN stored by a HA.
- CoA of the FN stored by a FA network. Each time a node changes its address, a copy of the new CoA is added at the HA. The location of MN is discovered by following the chain of CoAs until the node is reached.

B. Distributed Mobility Anchoring

Most mobility management systems let the mobility anchoring reside on a similar nature of the network entities, e.g., MARs, MAGs, LMAs, and CMDs. In the proposed system, the mobility management and its associated functions should be distributed. The scheme should be able to decide a suitable candidate for a particular function instead of assigning it to a default device at a default network element. For example, if a certain router is currently managing the forwarding function, and the distance to the MN exceeds certain hop count then this router may delegate its forwarding function to another router close to the MN 's current PoA.

C. IPv6 Based Network

Even before the exhaustion of IPv4 address space in 2012, networks were being moved from IPv4 to IPv6 based networks [30]. The research community in the field of mobile networks is also budging towards implementations using IPv6 or its extension. It is hence safe to assume that the future research in the field of VANETs will be based on IPv6 based networks. Using IPv6 will allow a good comparison between the existing solutions and proposed architecture as most of the existing solutions are IPv6 based.

D. Microscopic Mobility Model

Appendix 1 describes the key mobility models in reference to this proposal. Microscopic mobility model allows depiction of exact position of node. Microscopic model is most suitable candidate to be considered in my research because only few vehicles are involved during the handoff process and mobility management is relative to the position of a particular vehicle [31]. Further, microscopic mobility model is helpful for the appropriate analysis of control messages, their quantity, and total period required; therefore it allows a good estimation of parameters.

E. Freeway Traffic Model

The freeway model reduces complexity of simulation as it decreases congestion and road infrastructures elements (see Appendix 2 for Road Topologies). Further, speed and direction of nodes in freeway traffic model is relatively less intricate as due to similar pattern and direction of nodes movement. This allows a simplified comparison of centralized and distributed mobility management solutions for VANETs.

REFERENCES

[1] M. Annoni and B. Williams, "The History of Vehicular Networks," in Vehicular ad hoc Networks, Springer, pp. 3-21, 2015.

[2] H. Hartenstein and K. P. Laberteaux, "A tutorial survey on vehicular ad hoc networks," Communications Magazine, IEEE, vol. 46, no. 6, pp. 164-171, 2008.

[3] D. Liu, J.-C. Ziga, P. Seite, A. Chan and C. Bernardos, "Distributed Mobility Management: Current practices and gap analysis," 2014.

[4] J. Rosenberg, H. Schulzrinne, G. Camarillo, A. Johnston, J. Peterson, R. Sparks, M. Handley and E. Schooler, "SIP: Session Initiation Protocol," RFC Editor, 2002.

[5] K. Zhu, D. Niyato, P. Wang, E. Hossain and D. In Kim, "Mobility and handoff management in vehicular networks: a survey," Wireless communications and mobile computing, vol. 11, no. 4, pp. 459-476, 2011.

[6] S. J. Koh, M. J. Lee, M. Riegel, M. L. Ma and M. Tuexen, "Mobile SCTP for transport layer mobility," draftreigel-sjkoh-sctp-mobility-04. txt, Internet draft, IETF, 2004.

[7] A. C. Snoeren and H. Balakrishnan, "An end-to-end approach to host mobility," in Proceedings of the 6th annual international conference on Mobile computing and networking, 2000.

[8] S. Katti and S. S. Sambare, "Survey of different Solutions for Simultaneous Mobility Problem using mSCTP Protocol," International Journal of Computer Applications, vol. 120, no. 11, 2015.

[9] S. Mohanty and I. F. Akyildiz, "Performance analysis of handoff techniques based on mobile IP, TCP-migrate, and SIP," Mobile Computing, IEEE Transactions on, vol. 6, no. 7, pp. 731-747, 2007.

[10] J.-T. Park, S.-M. Chun, J.-H. Choi and S.-M. Lee, "Simple mobility management protocol for global seamless handover," in Consumer Communications and Networking Conference (CCNC), 2012 IEEE, 2012.

[11] D. Johnson, C. Perkins and J. Arkko, "Mobility Support in IPv6," RFC Editor, 2004.

[12] H. Soliman, C. Castelluccia, K. ElMalki and L. Bellier, "Hierarchical Mobile IPv6 (HMIPv6) Mobility Management," RFC Editor, 2008.

[13] H. Jung, E. Kim, Y. I. JongWha and H. Lee, "A scheme for supporting fast handover in hierarchical mobile IPv6 networks," ETRI journal, vol. 27, no. 6, pp. 798-801, 2005.

[14] V. Devarapalli, R. Wakikawa, A. Petrescu and P. Thubert, "Network Mobility (NEMO) Basic Support Protocol," RFC Editor, 2005.

[15] D. Yogesh and S. Singh, "A Review Paper on Various Mobility and Handover Methods in VANET," International Journal of Engineering and Technical Research, 2015.

[16] H. Chan, D. Liu, P. Seite, H. Yokota and J. Korhonen, "Requirements for Distributed Mobility Management," RFC Editor, 2014.

[17] K.-W. Lee, W.-K. Seo, Y.-Z. Cho, J.-W. Kim, J.-S. Park and B.-S. Moon, "Inter-domain handover scheme using an intermediate mobile access gateway for seamless service in vehicular networks," International Journal of Communication Systems, vol. 23, no. 9-10, pp. 1127-1144, 2010.

[18] Y.-S. Chen, C.-H. Cheng, C.-S. Hsu and G.-M. Chiu, "Network Mobility Protocol for Vehicular Ad Hoc Networks," in IEEE Wireless Communications and Networking Conference, 2009.

[19] L. Osborne, A. Abdel-Hamid and R. Ramadugu, "A performance comparison of Mobile IPv6, hierarchical Mobile IPv6, and Mobile IPv6 regional registrations," in Wireless Networks, Communications and Mobile Computing, 2005 International Conference on, 2005.

[20] B.-D. Shin and K.-J. Ha, "An improvement of handoff latency by virtual MAPs for HMIPv6," in Computer and Information Technology, 2006. CIT'06. The Sixth IEEE International Conference on, 2006.

[21] R. Li, J. Li, K. Wu, Y. Xiao and J. Xie, "An enhanced fast handover with low latency for mobile IPv6," Wireless Communications, IEEE Transactions on, vol. 7, no. 1, pp. 334-342, 2008.

[22] S. Gundavelli, K. Leung, V. Devarapalli, K. Chowdhury and B. Patil, "Proxy Mobile IPv6," RFC Editor, 2008.

[23] Q. B. Mussabbir, W. Yao, Z. Niu and X. Fu, "Optimized FMIPv6 using IEEE 802.21 MIH services in vehicular networks," Vehicular Technology, IEEE Transactions on, vol. 56, no. 6, pp. 3397-3407, 2007.

[24] L. Oliva, A. De, A. Banchs, I. Soto, T. Melia and A. Vidal, "An overview of IEEE 802.21: media-independent handover services," Wireless Communications, IEEE, vol. 15, no. 4, pp. 96-103, 2008.

[25] A. Prakash, S. Tripathi, R. Verma, N. Tyagi, R. Tripathi and K. Naik, "Vehicle assisted cross-layer handover scheme in NEMO-based VANETs (VANEMO)," International Journal of Internet Protocol Technology, vol. 6, no. 1-2, pp. 83-95, 2011.

[26] P. Sornlertlamvanich, S. Kamolphiwong, R. Elz and P. Pongpaibool, "NEMO-based distributed mobility management," in Advanced Information Networking and Applications Workshops (WAINA), 2012 26th International Conference on, 2012.

[27] B. Haberman, Distributed Mobility Management, 2016.

[28] C. J. Bernardos, A. de la Oliva and F. Giust, "A PMIPv6-based solution for Distributed Mobility Management," Internet Engineering Task Force, 2016.

[29] C. J. Bernardos, A. de la Oliva and F. Giust, "An IPv6 Distributed Client Mobility Management approach using existing mechanisms," Internet Engineering Task Force, 2016.

[30] S. H. Gunderson, "Global IPv6 statistics-measuring the current state of IPv6 for ordinary users," Google White Paper, 2008.

[31] F. J. Martinez, C. K. Toh, J.-C. Cano, C. T. Calafate and P. Manzoni, "A survey and comparative study of simulators for vehicular ad hoc networks (VANETs)," Wireless Communications and Mobile Computing, vol. 11, no. 7, pp. 813-828, 2011.